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EXOTIC FISH INTRODUCTIONS IN TEXAS

by

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ABSTRACT

The mission of Texas Parks and Wildlife Department's fisheries program is to manage the State's waters for the best fishing possible without depletion or waste of the resource. Through surveys we monitor, evaluate and report on the condition of the fisheries. Our management options fall into three broad categories — resource protection, increasing utilization of existing fisheries, and increasing fisheries for additional recreation and harvest. The first option is primarily the responsibility of our Resource Protection Branch with other branches within the Fisheries Division helping with pollution surveys and evaluation of environmental documents. The latter two options contain the main fishery program activities for the state.

Increased utilization of existing fisheries is accomplished through activities designed to provide access and facilities, fishing information, and fish attractors. Increasing the sport fishery resource involves habitat improvement, population manipulation and non-native fish stocking activities. Of these activities, non-native fish stocking is emphasized. Fisheries management is proceeding toward increasing predator diversity where man has altered aquatic systems. Fishes are matched with existing habitat and forage to bring about "balance" within fish communities.

The introduction of new species in Texas is not a recent development. For instance, the U.S. Fish Commission stocked American shad and California salmon prior to 1875. Herring and rainbow trout were stocked in 1882. The

Commission supplied German carp for stocking from 1880-1886. They stocked goldfish in 1885-1887. In the 1930's the Bureau of Fisheries were stocking Rio Grande perch, trout, smallmouth bass and others. Most introductions were unsuccessful at providing self-sustaining populations with the exception of carp.

The Texas Parks and Wildlife Department has stocked many non-endemic fishes over the past 10 years. The most successful in terms of fishermen benefit are Florida and smallmouth bass, walleye, striped bass and its white bass hybrid, and rainbow trout. The first four fishes of the above list have self-sustaining populations in the state. Northern pike and its hybrids with muskellunge and chain pickerel, muskellunge, shoal bass and coho salmon have been introduced on a limited scale, but strong populations have never developed and introductions of these species have been discontinued.

Both fresh and salt water fishes are currently being evaluated for management introduction activities. These are Firehole and redband trouts, coppernose bluegill, peacock bass, Nile perch, red drum, southern flounder, starry flounder, snook, spotted seatrout, orangemouth corvina, totoaba, and blueback herring.

The search for suitable fishes to increase diversity in sport fisheries is intensifying. Faced with constantly increasing fishing pressure and decrease in reservoir construction, biologists must manage existing waters more efficiently to maintain or improve fish harvest. Introduction of appropriate fish combinations to establish community stability is efficient management of the sport fishery resource.

SIGNIFICANCE OF NONNATIVE FISH INTRODUCTIONS IN TEXAS

by

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ABSTRACT

The number of exotic fishes established in Texas waters continues to increase. The details of any statistic would depend on the definition of the word exotic -- a more or less political definition incorporating national boundaries vs. a biological orientation incorporating nonnative introduction. I opt for the latter as the biological impacts are those most important in consideration of fishery biology programs. A minimum of 31 fishes now have established populations at least 100 km beyond their natural ranges (15 of these were not previously part of the Texas fish fauna). The impact(s) of these exotics should assist in guiding consideration of future releases. Research on such impacts is urgently needed for adequate development planning of Texas fishery resources. All planning should maximize prerelease studies as deferral of the release can merely postpone the benefits, but a release that results in an established breeding population (=biological success) will be irreversible with regard to environmental damage.

OVERVIEW OF TEXAS PARKS AND WILDLIFE DEPARTMENT'S FLORIDA LARGEMOUTH BASS PROGRAM

by

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ABSTRACT

Florida largemouth bass, Micropterus salmoides floridanus, were introduced into Texas in 1971 when fingerlings were transported from Florida to the Tyler State Fish Hatchery. These fingerlings were used to begin building the hatchery brood stock which initiated the Florida bass program. The objective for introducing Florida bass was to increase the quality of largemouth bass fisheries to provide the fishermen of Texas with the opportunity for more recreation hours and greater sport fish harvest. Florida bass were expected to accomplish this by providing a faster growing largemouth bass with an increase in production of trophy-sized fish. In addition, it was believed the reported differences in the life history of the Florida bass, compared to northern largemouth bass, M. s. salmoides, would result in better utilization of existing forage and habitat and increase standing crops of largemouth bass.

To accomplish the program objective, private and public reservoirs were stocked with Florida bass beginning in 1973. Since that time, 172 public lakes have been stocked. Age and growth studies in Texas waters indicate northern bass grow slightly faster than Florida bass during their first year of life. In subsequent years, Florida bass grow at substantially faster rates. Mean size of largemouth bass caught and incidence of trophy-sized fish has increased in reservoirs where Florida bass have been successfully introduced. In February 1980, a 14.1 lb Florida bass was caught from Lake Monticello. This

fish replaced the Texas record largemouth bass which had stood for 37 years. In 1981, two more record bass were caught establishing our current record of 15.5 lb.

Another key difference in the life history of Florida bass compared to the northern bass is its habitat preference. Florida bass, because of the shallow, highly vegetated lakes it evolved in, does not occupy the identical habitat as the northern bass. Therefore, the introduction of the Florida genotype was expected to increase utilization of more or different forage fishes, of different spawning areas, and of a wider range of water depths. This increases the adaptability of largemouth bass to a wider range of resources within a reservoir and increases bass production. Reservoirs where Florida bass have been established have consistently higher standing crops of bass.

Florida bass have become a significant part of largemouth bass fisheries in reservoirs across the state. Creel surveys indicate increased fishing pressure and harvest with angling of exceptional quality. The ability of this fish to accomplish program objectives has been clearly demonstrated by fisherman success and evaluation results.

OVERVIEW OF TEXAS PARKS AND WILDLIFE DEPARTMENT'S STRIPED BASS PROGRAM

by

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ABSTRACT

The goal of the striped bass program is to increase fishing recreation and fish harvest by more efficient utilization of available habitat. The program objective for accomplishing this goal is to provide a pelagic, trophy predator which can convert underutilized prey fish biomass to desirable sport fish biomass. The intent of striped bass and hybrid striped bass (white bass x striped bass) introductions is to complement existing sport fish stocks, not replace them.

Concerted efforts to establish striped bass and hybrids began in 1967 and 1972, respectively. Both fish have demonstrated their ability to utilize overabundant prey fish populations and establish popular recreational fisheries. To date, 17.1 million striped bass have been stocked in 27 lakes and 16.2 million hybrids have been stocked in 80 lakes. Although assessment of stocking success has been somewhat subjective, failures to establish fisheries have been minimal. Attempts to establish populations in coastal waters have met with only limited success.

Only Lakes Texoma and Whitney have documented evidence of natural striped bass reproduction. All other striped bass and hybrid populations are maintained on a put-grow-and-take basis. Average annual production is about 2.8 million fingerlings and is fairly evenly divided between stripers and hybrids.

With two exceptions, where harvest was overly restricted, no adverse impacts on prey fish populations have been found. No deleterious effects on other sport fishes has been shown. Angler acceptance has been extremely good, as evidenced by the boom in sales of specialized striped bass and hybrid fishing tackle.

Advancements in culture and stocking techniques have been made which should improve our capability to establish and maintain fisheries. Results from tank spawning, zooplankton production, and fry stocking experiments have been particularly encouraging and should contribute towards a more cost effective program.

The temperature/eutrophication problem associated with striped bass populations in many parts of the country may exist in some Texas waters. Adult striped bass sometimes show a preference for cool, well oxygenated water in summer which may greatly limit the amount of available habitat and create stress conditions. Telemetry studies have been initiated at Lake Whitney to determine movement, seasonal migration patterns, and temperature preferences. This information could be important in selecting lakes for future striped bass introductions.

OVERVIEW OF TEXAS PARKS AND WILDLIFE DEPARTMENT'S WALLEYE AND SMALLMOUTH BASS PROGRAMS

by

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ABSTRACT

Since 1964, attempts have been made to establish walleye populations in Texas reservoirs to provide an additional sport fish and a predator capable of utilizing overabundant forage and stunted sunfish populations. Prior to 1979, walleye fingerlings were stocked at rates varying from 50 to 500/hectare and fisheries developed only in four reservoirs where reproduction occurred. Since 1979, seven Texas reservoirs have been stocked using experimental stocking rates of 5,000 - 12,000 fry/hectare. With the initiation of this new stocking strategy, walleye populations have been established which are large enough to provide excellent fisheries and significantly change populations of forage and stunted sunfishes.

The smallmouth bass program was initiated in 1974 to improve the quantity and quality of bass in Texas reservoirs. Introductions have been made in 26 reservoirs and eight streams. Fisheries have developed in nine reservoirs and one stream where natural reproduction has occurred. The most successful fisheries have developed in deep, clear, rocky reservoirs in the central, western and northwestern areas of the state. The establishment of smallmouth bass in reservoirs with suitable habitat has not affected the catch of largemouth bass but has increased the overall catch of bass.

AQUATIC VEGETATION CONTROL WITH WHITE AMUR
IN LAKE CONROE, TEXAS

by

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ABSTRACT

Lake Conroe, a 8,505-hectare reservoir on the San Jacinto River, was stocked between 3 September, 1981 and 12 September, 1982 with 270,000 white amur (*Ctenopharyngodon idella*) for vegetation control. Since impoundment in 1973, Lake Conroe has experienced a rapid development of aquatic weeds, most of which has been the exotic *Hydrilla verticillata*. At the time stocking commenced, over 3,500 hectares of aquatic weeds were present, as determined by aerial infrared photographic surveys.

A total of 243 white amur were collected in cove rotenone samples in May, 1982. Analysis of scale data indicated growth had been very rapid for those fish stocked in the fall of 1981, and that survival was good, particularly for the smaller fish stocked. Maximum size to date has been 5.1 kg, and preliminary examination of gut contents indicates these fish are feeding extensively and exclusively on aquatic vegetation.

A METHOD FOR DIRECTLY ESTIMATING THE TAG REPORTING RATE OF ANGLERS

by

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ABSTRACT

Tag-reporting rates for marine recreational boat anglers were estimated directly by surreptitiously implanting fish tags into fish that had already been caught during routine creel surveys during October, 1976-September, 1978. Twenty-nine percent (177) of the 600 implanted tags were returned. Ninety-five percent of all tags returned were received within 100 days after they had been implanted. Significant differences ($P \leq 0.05$) were found among reporting rates by anglers from different areas and for different species of fish. No significant differences were found for reporting rates by anglers among seasons or years. These results indicate that use of reward tags in other studies has not fully corrected for nonreporting of recovered tags and, consequently, fishing mortality estimates based on them have been underestimate The vast majority of anglers (96%) had correctly identified their fish to genus and reported fish lengths were within ± 76 mm (s.d.) of those determined by agency staff.

USE OF FORMALIN TO SEPARATE TADPOLES FROM LARGEMOUTH BASS FINGERLINGS AFTER HARVESTING

by

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ABSTRACT

Tadpoles of the Rio Grande leopard frog (Rana berlandieri) and fingerling largemouth bass (Micropterus salmoides) were exposed to formalin to test the ability of the chemical to selectively kill tadpoles without harming fish. Exposure of a mixture of tadpoles and fingerlings to 60 ul/l formalin for 24 hours killed 100% of tadpoles while all fingerlings survived the exposure period. Three percent of the bass died within the 5 days following exposure. In tests using 200 ul/l of formalin for 1 hour and then diluting the solutions at the rate of 1.2 turnovers per hour, we killed all of the tadpoles within 24 hours of the initial exposure. All of the bass survived the exposure and survived the 5 days following the exposure that they were monitored. These data indicate that formalin can be used to selectively separate largemouth bass fingerlings from tadpoles after harvesting.

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STATUS REPORT ON PEACOCK BASS (CICHLA SPP.) IN TEXAS

by

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ABSTRACT

The Texas Parks and Wildlife Department is assessing the feasibility of using peacock bass, Cichla spp., as a sports fish/management tool in heated Texas reservoirs. Previous introductions of these cold-intolerant species have failed as a result of winter kills. However, approximately 4,500 C. ocellaris fingerlings, stocked in September, 1981 have successfully overwintered in Wilkes Reservoir in northeast Texas. Sexual maturity and successful spawning in spring, 1982 was documented. Preliminary indications of the impact of this introduction on the indigenous fish community are discussed.

INTRODUCTION

The Texas Parks and Wildlife Department is currently conducting research on two species of South American cichlids, Cichla ocellaris and C. temensis. The genus Cichla contains at least four species and is generally considered to be the most primitive group in the family Cichlidae. All members of the genus are commonly referred to as peacock bass in the United States. These two species are most accurately distinguished from one another by the number of lateral line scales, usually 80 for C. ocellaris and 105 - 110 for C. temensis (Machado-Allison 1971).

The research program is concerned with effects of large, tropical predators on population dynamics of fishes in heated power plant reservoirs.

These waters often become dominated by undesirable species such as carp, Cyprinus carpio, gizzard shad, Dorosoma cepedianum and blue tilapia, Tilapia aurea. The Department's goal is to provide a sport fish that can thrive in this abnormally warm environment and attain a large enough size to efficiently utilize available forage. Members of the genus Cichla seem particularly well suited by virtue of their neotropical origin and large adult size.

The peacock bass sensitivity to cool water temperature greatly lowers the potential for problems that often result from exotic species introductions. C. ocellaris has a lower lethal temperature of approximately 16 C (Guest et al. 1979), while that of C. temensis is 17 C (Guest and Lyons 1980). Slightly higher temperatures also have detrimental effects, e.g., C. ocellaris stop feeding around 17 C. Therefore, peacock bass introduced into selected warm-water reservoirs should be confined to those systems by ambient winter temperatures of the surrounding watersheds.

LIFE HISTORY

Reports on fecundity of C. ocellaris vary from 3,000 - 5,000 eggs/spawn (Fontenele 1950) to more than 10,000 eggs/spawn (Zaret 1980). C. temensis is also reported to produce approximately 10,000 eggs/spawn (Fontenele 1950). C. ocellaris can reach sexual maturity in less than 12 months at an average size of 330 mm standard length (SL) and attains a maximum size of approximately 700 mm total length (TL) and 7 kg in weight (Zaret 1980). In their native habitat, C. ocellaris spawn in response to favorable conditions such as the rainy season (Zaret 1980). In hatchery research ponds, individuals have been observed to spawn repeatedly and, given the right conditions, would probably spawn continuously throughout the year. Both species provide parental care of eggs and young.

Spawning usually occurs in shallow water on a horizontal surface such as a rock or log (Zaret 1980). These structures are provided in our research ponds and are utilized by the brooders. Upon hatching, larvae are moved to a small, shallow nest the parents have dug in the bottom. After several days larvae become free swimming and school around the parents. Parents actively guard the school during this period and, reportedly, do not eat (Zaret 1980). Zaret found when the young are 60 - 70 mm SL (8 - 10 weeks old) they leave the parents, move to littoral vegetation and remain there for about 5 months (180 mm SL). Our research ponds are the functional equivalent of a vegetated littoral zone and there juveniles have remained in a school with the parents up to a length of approximately 150 mm SL at which time they were removed from the pond. In nature, they continue to school until they reach sexual maturity (Zaret 1980).

CULTURE PROCEDURES

Cichla spp. have been maintained and studied at Heart of the Hills Research Station since 1974 (Rutledge and Lyons 1976). During the cooler months, September through May, the fishes are held indoors in 30,000-liter tanks. Water is maintained at 26 - 28 C by submersible electric heaters and filtered through 1,800-liter, biological filters. They are fed goldfish, Carassius auratus, and sunfishes, Lepomis spp., three times per week, ad libitum. Four-hour prophylactic bath treatments with malachite green (0.04 ppm) are administered weekly to control fungus and external parasites.

From June through August the fishes are held in hatchery research ponds. They range in size from 1.5 - 7.0 kg and are stocked at densities no greater than one fish/0.1 hectare. Brood fish are sexed by presence/absence of a nuchal hump, typical of sexually active males, and paired accordingly.

Adults are fed sparingly with goldfish. A large number of forage fishes, particularly goldfish, will interfere with harvesting the young Cichla to be produced. The onset of reproductive activities is manifested by the presence of a cleared nest with an attendant pair of peacock bass. Larval peacock bass are planktivores and, therefore, require a plankton bloom to provide sufficient forage in ponds. This is accomplished by periodically fertilizing the ponds throughout the spawning season. In late summer, fingerlings are collected by slowly draining the ponds through a screen filter and netting them from shallow water.

STOCKING AND MONITORING

Cichla spp. have been stocked in selected, Texas electro-power plant reservoirs for the last 4 years. In September, 1979, Lake Bastrop, Bastrop County, was stocked with approximately 3,000 fingerlings ($\overline{TL}$ = 75 mm) and 104 adult (250 - 300 mm TL) C. ocellaris and C. temensis (Lyons 1980). A power plant breakdown for several weeks that winter, resulted in a total kill of peacock bass.

Coleto Creek Reservoir, Goliad County, was stocked in September, 1980 with 50 adult (250 - 280 mm TL) C. ocellaris and approximately 4,000 fingerling (TL = 65 mm) C. ocellaris and C. temensis. The power plant broke down during the coldest days of that winter decimating the population.

Wilkes Reservoir, Upshur County, was the September, 1981 stocking site. To date, the introduction in this 265-hectare private impoundment can be termed a success. Adults of both C. ocellaris (13) and C. temensis (8), ranging in size from 300 to 380 mm TL, were stocked and successfully overwintered. Approximately 4,500 fingerling C. ocellaris ($\overline{TL}$ = 75 mm) were also stocked and with an average growth rate of 22 mm/month (Fig. 1) they were reproductive by May, 1982. While power plant failure has not yet occurred at this facility, winter shutdowns will inevitably occur at any power plant and restocking of appropriate reservoirs will be a necessary part of this program.

Several parameters are being monitored at Wilkes Reservoir in order to determine the impact of the peacock bass introduction on the indigenous fish community. Peacock bass data is collected only for *C. ocellaris* since no reproduction by *C. temensis* has been recorded. Data gathered on a tri-monthly schedule include: age and growth of *C. ocellaris*, largemouth bass, *Micropterus salmoides*, bluegill, *Lepomis macrochirus* and channel catfish, *Ictalurus punctatus*; seasonal distribution patterns of above species; prey items utilized by *C. ocellaris* and *M. salmoides*, and gonosomatic index for *C. ocellaris*. Estimates of standing crop are made annually using cove rotenone surveys.

While only preliminary observations are possible at this point, we have found that in accordance with studies of native populations of *Cichla* (Lowe-McConnell 1969), *C. ocellaris* was found to be a nonselective predator, taking prey items that occur in greatest abundance. In the case of Wilkes Reservoir, the diet consists almost entirely of sunfishes, *Lepomis* spp. Seventeen specimens (119 - 265 mm SL) had identifiable prey items in their gut; these were *Lepomis* spp. and one brook silverside, *Labidesthes sicculus*.

Cove rotenone data (2 coves, 1.5 hectares), taken in June, 1982, shows *C. ocellaris* to be at a density of approximately 244/hectare (4.4 kg/hectare). Original stocking density was approximately 10/hectare. Although it is premature to make any determinations of population changes, it is interesting to note some of the contrasts between the June, 1981 and 1982 cove rotenone data. In 1982, largemouth bass were at a density of approximately 17/hectare (1.8 kg/hectare) down from the 1981 figure of 113/hectare (16.8 kg/hectare). Warmouth, *L. gulosus*, were estimated to have increased in number by almost 30%

and 13% in kg/hectare (i.e., more, smaller fish). Spotted gar, Lepisosteus oculatus, appear to have increased by almost 75% in both number and kg/hectare. There were other variations in standing crops, but, these three were the most dramatic. While these population changes were coincidental with the introduction of Cichla spp., it is unlikely that peacock bass were the primary causative agent. In the case of M. salmoides, decreases in number were at all sizes and there were probably not enough large peacock bass to have effected a change of this magnitude through predation. Standing crop perturbations resulting from competitive interactions are usually subtle and take much longer to be detected. The observed changes in the fish community were more likely due to normal population fluctuations and sampling error inherent in cove rotenone surveys. Peacock bass will almost certainly have an effect on the population structure in Wilkes Reservoir, but several years will be necessary before their influence can be quantified.

Tradinghouse Creek Reservoir, McLennan County, was stocked with approximately 1,600 fingerling C. ocellaris (25 - 180 mm TL) in September, 1982. A monitoring program similar to that in Wilkes Reservoir will be initiated in February, 1983. Presumably, information gathered from these reservoirs will help determine the relative benefits of adding this South American predator to the existing fauna and, hopefully, will provide a management strategy for better utilizing environments created by power plant reservoirs.

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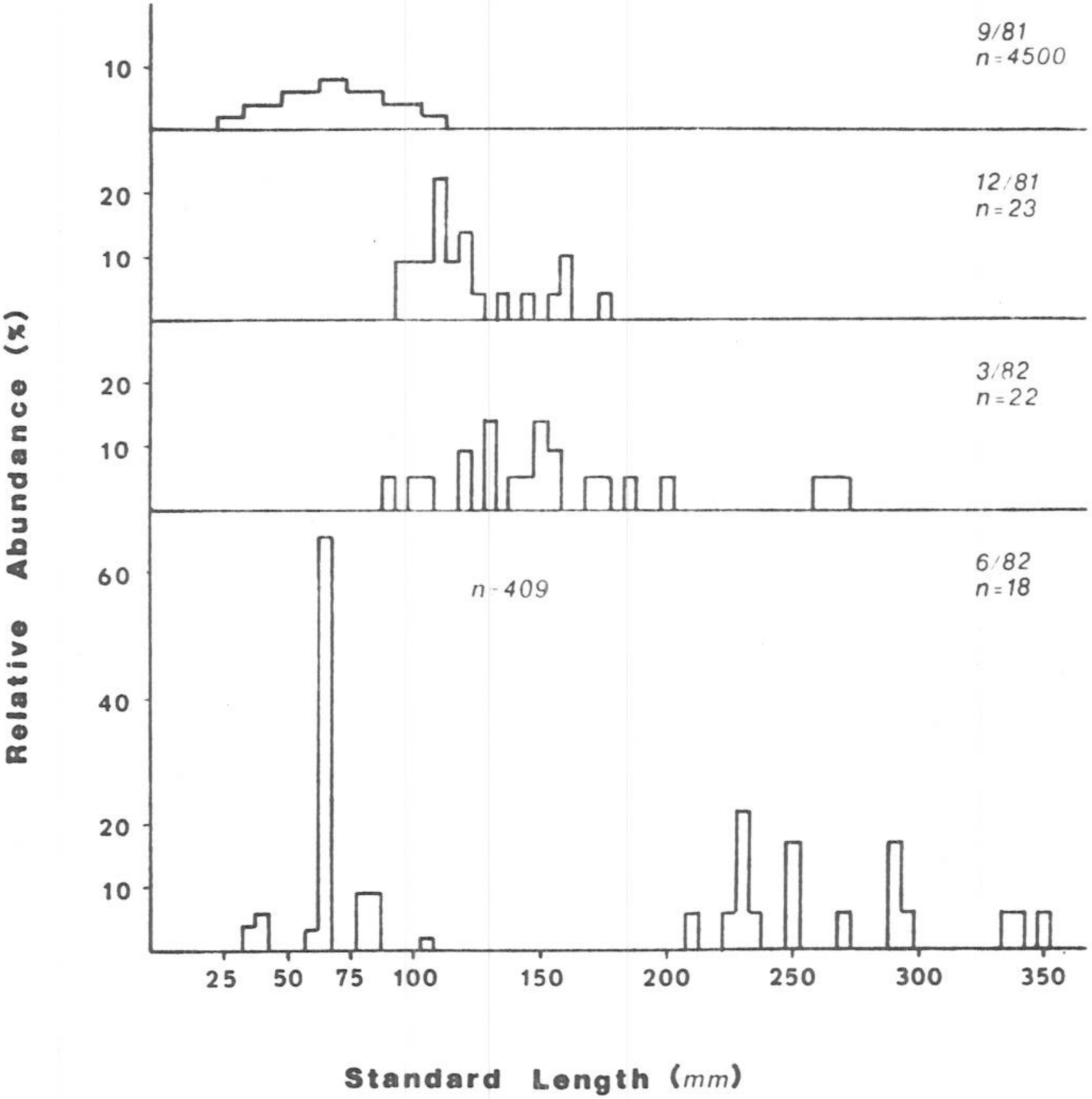
Figure 1. Tri-monthly size distributions of Cichla ocellaris in Wilkes Reservoir. Adults stocked in September, 1981 are not considered since they did not appear in subsequent collections. The two size classes in June, 1982 are treated separately.


Relative Abundance (%)
10
9/81
n=4500
20
10
12/81
n=23
20
10
3/82
n=22
60
n=409
6/82
n=18
40
20
10
25
50
75
100
150
200
250
300
350
Standard Length (mm)

✓

RELATION BETWEEN GROWTH, MORTALITY AND PROPORTIONAL STOCK DENSITY OF LARGEMOUTH BASS IN TEXAS RESERVOIRS

by

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ABSTRACT

A multiple regression equation was developed to predict the effects of growth and mortality on Proportional Stock Density (PSD) of largemouth bass (Micropterus salmoides) in Texas reservoirs. Age at 254 mm total length (Age_{254}), per cent annual mortality (A), and PSD were calculated for largemouth bass from 40 reservoirs. The mean Age_{254} was 1.85 years; mean A was 55.6%; mean PSD was 38.6%. The equation, $PSD = 130 - 32.3\ (Age_{254}) - 0.573\ (A)$, explained 71% of the variation in PSD. This equation should be useful to reservoir managers in establishing PSD targets on a reservoir by reservoir or regional basis.

INTRODUCTION

Proportional Stock Density (PSD) is a structural index for the assessment of fish populations. This index is based on length-frequency distributions and defined as the percentage of stock fish that are of quality size (Anderson 1976). Stock fish are those larger than or equal to the length at which the majority of the population reaches maturity, while quality fish are of the size that most anglers like to catch (Anderson and Weithman 1978). Proportional Stock Density is dependent upon growth and mortality rates. These rates are influenced by a multiplicity of factors (Bennett 1970; Royce 1972) which work in conjunction to collectively influence population structure. Proportional Stock Density attempts to consolidate these complex ecological interactions into a methodologically simple management tool.

Largemouth bass (Micropterus salmoides) is the most sought after game fish in Texas (unpublished data, Texas Parks and Wildlife Department, Austin, Texas) and, therefore, biologists must devote much time to its management. Because PSD requires few data that can be collected at a relatively low cost, it is becoming increasingly popular among fisheries managers as a method of evaluating largemouth bass populations. Using a structural model with growth estimates from Midwestern ponds and 30 - 50% annual mortality, Reynolds and Babb (1978) determined that PSD values of 40 - 60% are desirable. Although such target values may be applicable to certain regions in Texas, the wide range of growth rates observed in the state (Prentice and Durocher 1979) precludes their general use when balanced populations are desired.

This paper quantifies the relationship between growth, mortality and PSD of largemouth bass in Texas reservoirs. The approach is to derive a multi-variable model based on empirical data. The study was conducted to provide fishery managers with approximate PSD targets compatible with growth and mortality rates exhibited by largemouth bass in state waters.

METHODS

Growth, mortality and PSD were calculated for largemouth bass from 40 reservoirs ranging in size from 20 to 31,688 hectares (mean = 4,208 hectares). Data were collected from April through September, 1976 through 1981, by biologists of the Texas Parks and Wildlife Department. Collections were made by electrofishing and/or cove rotenone sampling as part of standardized fish population surveys conducted throughout Texas. Samples for individual reservoirs were collected during a single year, and combined when more than one was available.

Growth of largemouth bass was described as the average age (in years) at which fish in a population reach a given body length. The age at which largemouth bass reach the statewide minimum length limit (254 mm total length) was chosen as the estimator of growth (Age_{254}) because it indicates rate of recruitment into harvestable size classes. Age_{254} was determined for each population with the von Bertalanffy growth model as described by Everhart et al. (1975). Annual growth estimates used in the model were calculated using the Lee method of back calculating lengths of fish from scales (Everhart et al. 1975). These estimates should be regarded as approximations since a) time of the year of annulus formation varies between fish and years, b) the period between hatching and formation of first annulus is slightly less than 1 year, and c) they describe only growth rates achieved by survivors.

Estimates of annual mortality (A) were derived from the average size of fish $\geqslant 254$ mm present in the population (the greater the mortality the smaller the average size), and from parameters of the von Bertalanffy growth model (Beverton and Holt 1956, as cited in Ricker 1958). The formula assumes that mortality rate is constant over the range of ages involved, that the population is in equilibrium with respect to the prevailing mortality rate, that variations in year-class strength are not great enough to affect the result, and that the catch is representative of the population (Ricker 1958). Inasmuch as the assumptions are not always met the formula provides a rough estimate of A. The quality of these estimates can be suggested by reason of their agreement with other population estimates.

Proportional Stock Density was calculated according to Anderson (1976) by dividing the number of largemouth bass of quality size ($\geqslant 305$ mm) by the total number longer than or equal to minimum stock size (203 mm) and multiplying the quotient by 100. A sample of 25 or more (mean = 40; range =

25 - 116) stock size largemouth bass was available from each study reservoir.

A multiple regression procedure was used to regress values of PSD on Age_{254} and A. The regression model determines what population structure is to be expected from given levels of growth and mortality by estimating the mean value of the dependent variable for any given value of the independent variables. The model is described as:

$$Y = a + b_1x_1 + b_2x_2 \tag{1}$$

where Y represents PSD, x_1 and x_2 the independent variables (Age_{254} and A); b_1 and b_2 the partial regression coefficients for each independent variable; and a the y-intercept.

RESULTS

Average Age_{254}, A and PSD of the 40 reservoir sample was 1.85 years, 55.6% and 38.6% respectively (Table 1).

The multiple regression procedure provided the following equation:

$$PSD = 130 - 32.3(Age_{254}) - 0.573(A). \tag{2}$$

The independent variables account for 71% ($R^2 = 0.71$) of the variation in PSD and both contribute significantly ($P < 0.01$) to accuracy of prediction (Table 2). Predicted PSD were obtained for various values of Age_{254} and A (Table 3).

MANAGEMENT IMPLICATIONS

The significant relationship observed between PSD and rates of growth and mortality suggests a) methods used for estimating values of each variable are sufficiently reliable, and b) PSD targets should be determined on a reservoir by reservoir basis, or at least by region, to ensure they are compatible with the system in question.

How to Use this Model to Determine Lowest Acceptable PSD

Regional or reservoir specific PSD can be predicted with formula (2) or Table 3, using approximate growth rates and sustainable estimates of annual mortality. Approximate growth rates of largemouth bass (Age_{254}) in Texas, by river system and ecological area, are given by Prentice and Durocher (1979). Growth rates by reservoir can be determined empirically or predicted using physical and biological data as described by Miranda and Durocher (in press). Sustainable estimates of annual mortality can be calculated from growth data. Annual mortality must not exceed annual growth for a population to remain constant, hence, in 1 year the percent largemouth bass $\geqslant 254$ mm dying must not exceed the percent becoming 254 mm. Growth and mortality rates representing an existent largemouth bass population should be applied cautiously since, if inadequate, could provide an improper PSD target.

The model can be applied to determine the lowest acceptable PSD in a hypothetical reservoir, or region, where average Age_{254} is expected to be 1.85 years. Since largemouth bass should become 254 mm in an average 1.85 years, theoretically in a 1.85-year period all members $\geqslant 254$ mm may die and the population size still remain constant. Therefore, maximum sustainable mortality in a 1.00-year period is 54% (100 x 1/1.85). The lowest acceptable PSD is obtained by inserting these rates ($Age_{254} = 1.85$ and $A = 54$) in equation (2) and equals 39%. A factual PSD value below 39% would suggest poor growth or excessive mortality, providing the sample is representative of the population.

Sampling Considerations

Largemouth bass distribution within a reservoir varies daily and seasonally. Therefore, when a measured PSD is to be compared with a target, the time of day and the season sampled should be considered. In West Point Reservoir, Alabama-Georgia, no differences in PSD values between paired day-night samples were observed. However, differences did exist in the fall when recruit-size largemouth bass influx the shoreline and lower the night PSD (Sonski 1982). Measures of PSD (day and night combined) taken in spring, summer and fall were not different in that reservoir. Nevertheless, biomass of largemouth bass in littoral zones should be highest in spring, therefore, the most accurate estimates of PSD may be obtained then. To minimize variation due to seasonal population changes, comparison of PSD between years, and reservoirs, should involve estimates from data taken during the same season.

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Table 1. Estimates of age in years at 254 mm total length (Age_{254}), % annual mortality of fish $\geq$254 mm total length (A), and Proportional Stock Density (PSD) of largemouth bass in 40 Texas reservoirs. Data were collected from 1976 through 1981.

Reservoir	Age_{254}	A	PSD
Amistad	1.82	42.7	51.4
Averhoff	2.40	84.6	11.4
B.A. Steinhagen	1.74	63.8	34.5
Brady Creek	1.77	50.7	50.0
Champion Creek	1.82	59.0	39.9
Corpus Christi	1.84	64.9	41.5
Cypress Springs	1.49	59.8	77.8
E.V. Spence	1.28	55.1	47.0
Fairfield	1.44	54.4	38.6
Falcon	1.49	69.4	28.9
Fayette County	1.90	43.7	52.6
Fort Phantom Hill	1.91	70.5	15.4
Grapevine	2.39	56.8	9.8
J.B. Thomas	2.88	23.9	23.4
Jacksonville	2.16	41.4	32.1
Marine Creek	2.06	62.8	20.8
McQueeney	1.92	76.2	15.5
Medina	2.24	68.2	11.5
Mexia	1.58	30.3	68.1
Mill Creek	1.64	46.7	65.8
Monticello	1.33	74.6	51.7
Murvaul	1.45	25.4	70.3
Nacogdoches	1.35	40.2	52.3
Nasworthy	1.92	22.8	39.9
Navarro Mills	1.95	78.8	26.7
Palestine	1.49	37.5	80.0
Palo Pinto	1.83	58.4	18.7
Proctor	1.76	47.2	44.4
Ray Hubbard	1.27	66.9	42.0
San Augustine City	2.50	73.0	3.4
Scarborough	1.70	37.9	51.7
Somerville	1.59	86.6	18.5
Squaw Creek	1.61	59.7	69.4
Stamford	1.43	35.5	68.2
Tawakoni	1.83	64.9	30.0
Trammel	2.10	47.1	26.2
Van City	2.99	77.3	4.3
Weatherford	1.76	83.4	38.6
W.E. Long	2.74	32.9	25.0
Welch	1.58	50.5	47.7
Reservoir average	1.85	55.6	38.6

Table 2. Regression statistics computed for the model $Y = a + b_1x_1 + b_2x_2$ fit to data of Table 1. The dependent variable Y is PSD. Here, b is a partial regression coefficient, SE is the standard error of b, t is Student's t for testing H_o: $b_i = 0$ against H_a: $b_i \neq 0$, and df is the degrees of freedom for this t-test.

Variable (x_i)	b_i	SE	t	df
Age (years) at 254 mm total length	-32.3	4.38	-7.387**	37
Annual mortality	-0.573	0.106	-5.406**	37
	a = 130			
	R = 0.84			

** $P < 0.01$

Table 3. Predicted Proportional Stock Density at various values of annual mortality and age at 254 mm total length (Age_{254}) in Texas reservoirs.

	ANNUAL MORTALITY (%)												
AGE_{254}	25	30	35	40	45	50	55	60	65	70	75	80	85
1.30	74	71	68	65	62	60	57	54	51	48	45	42	40
1.35	72	69	67	64	61	58	55	52	49	47	44	41	38
1.40	71	68	65	62	59	56	54	51	48	45	42	39	36
1.45	69	66	63	60	58	55	52	49	46	43	40	38	35
1.50	67	65	62	59	56	53	50	47	45	42	39	36	33
1.55	66	63	60	57	54	52	49	46	43	40	37	34	31
1.60	64	61	59	56	53	50	47	44	41	38	36	33	30
1.65	63	60	57	54	51	48	45	43	40	37	34	31	28
1.70	61	58	55	52	50	47	44	41	38	35	32	29	27
1.75	59	57	54	51	48	45	42	39	36	34	31	28	25
1.80	58	55	52	49	46	43	41	38	35	32	29	26	23
1.85	56	53	50	48	45	42	39	36	33	30	27	25	22
1.90	55	52	49	46	43	40	37	34	32	29	26	23	20
1.95	53	50	47	44	41	39	36	33	30	27	24	21	19
2.00	51	48	46	43	40	37	34	31	28	26	23	20	17
2.05	50	47	44	41	38	35	32	30	27	24	21	18	15
2.10	48	45	42	39	37	34	31	28	25	22	19	17	14
2.15	46	44	41	38	35	32	29	26	24	21	18	15	12
2.20	45	42	39	36	33	31	28	25	22	19	16	13	10
2.25	43	40	37	35	32	29	26	23	20	17	15	12	09
2.30	42	39	36	33	30	27	24	22	19	16	13	10	07
2.35	40	37	34	31	29	26	23	20	17	14	11	08	06
2.40	38	35	33	30	27	24	21	18	15	13	10	07	04
2.45	37	34	31	28	25	22	20	17	14	11	08	05	
2.50	35	32	29	27	24	21	18	15	12	09	06	04	
2.55	34	31	28	25	22	19	16	13	11	08	05		
2.60	32	29	26	23	20	18	15	12	09	06			
2.65	30	27	25	22	19	16	13	10	07	04			
2.70	29	26	23	20	17	14	11	09	06				
2.75	27	24	21	18	16	13	10	07	04				
2.80	25	23	20	17	14	11	08	05					
2.85	24	21	18	15	12	09	07	04					
2.90	22	19	16	14	11	08	05						
2.95	21	18	15	12	09	06							

Vol. 5

CORRECTIVE STOCKING OF FORAGE-DEFICIENT PONDS USING BLUEGILLS

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Eight ponds with established populations of largemouth bass (*Micropterus salmoides*) and forage other than bluegill (*Lepomis macrochirus*) were each stocked with 65-400 advanced bluegills/hectare. Seven of the eight populations were established on the first attempt. Bluegills showed no indication of overpopulating in any of the ponds. Bass populations which had been comprised of stunted individuals with low condition became characterized by larger individuals of higher condition within 1 year following bluegill introduction in some ponds. Responses in the three ponds larger than 1.5 hectares were more pronounced and occurred more quickly than in the two ponds less than 0.3 hectare. Corrective stocking with 75-100 bluegills/hectare at a minimum length of 75 mm is recommended.

INTRODUCTION

Recent pond management recommendations for Texas have included stocking bluegills (*Lepomis macrochirus*) as forage for largemouth bass (*Micropterus salmoides*) (Texas Chapter, American Fisheries Society 1980). These recommendations provide for the stocking of new or reclaimed ponds with bluegills as the principal forage species.

Because bluegills were not previously recommended or available to private landowners, many established bass ponds in the state lack bluegills. These ponds occasionally lack forage entirely, contain only hybrid sunfish which were available from Texas Parks and Wildlife Department for distribution to private waters, or have established populations of invading species such as green sunfish (Lepomis cyanellus), warmouth (L. gulosus), golden shiner (Notemigonus crysoleucas), or mosquitofish (Gambusia affinis). Occasionally other sunfish species have been stocked as forage, e.g., redear sunfish (L. microlophus), but these have been unable to sustain predation by largemouth bass (e.g., Gasaway 1968). In all of these combinations, bass tend to deplete their forage supply and stunt at sizes of marginal interest to most bass anglers.

Introduction of prey species into forage-deficient bass populations is difficult due to intense predation upon stocked fish. Currently Texas stocking recommendations do not include stocking rates and procedures for establishing bluegills into previously-established bass populations. The objective of this paper is to describe some effects of stocking bluegills into bass ponds lacking bluegills as forage.

METHODS

From 1978 to 1981, eight ponds were sampled by electrofishing which failed to produce bluegills where bass were established (Table 1). These ponds ranged in size from 0.05 to approximately 12.15 hectares and were located in Central and South Texas. Most ponds were clear, but two were moderately turbid (20-40 cm Secchi disk transparency).

Bluegills were typically stocked at rates of 65-250/hectare, depending upon availability of fish. In no case were fewer than 20 total bluegills stocked; this resulted in a stocking rate of 400/hectare in the smallest pond (0.05 hectare). In all cases, 75 mm total length (TL) was the smallest size of bluegills stocked. When available, bluegills up to 150 mm TL were used. Bluegills were collected from established populations by seining or electrofishing and transported immediately for stocking.

Bass and forage populations were monitored periodically in all ponds using electrofishing or seining. Additional data on bass were collected by hook-and-line sampling. Adequate numbers of bass were collected from five ponds to allow determination of changes in bass population structure and condition. With one exception, sampling was conducted at 1-year intervals for 1 to 3 years following bluegill introduction. Additional sampling during the intervening time was done in three ponds.

Coefficient of condition, K_{TL} (Carlander 1977), and relative weight, W_r (Wege and Anderson 1978) were calculated for all bass 152-400 mm TL. Minimum size for inclusion was based on the range of lengths described by Wege and Anderson's (1978) equation for standard weights of largemouth bass. Differences among means was tested by analysis of variance and those significantly different ($p<0.05$) from the mean at the time of bluegill introduction were determined by Duncan's multiple range test (Snedecor and Cochran 1980).

Size structure of the bass populations was described by relative stock density (RSD) modified from Wege and Anderson (1978). Although they suggeste a minimum stock size of 200 mm TL, we chose 152 mm TL as a minimum to correspond to the minimum size used in calculation of W_r. Using 152 mm TL as minimum stock size, RSD_{250} (percentage of bass stock over 250 mm TL) and RSD_{300} (percentage over 300 mm TL) values were calculated.

RESULTS AND DISCUSSION

Bluegills were established in seven of eight ponds following the first stocking. One pond (Old House II) required re-stocking when no bluegills wer found 1 year later. This second stocking (at 125 fish/hectare), although at half the rate of the first, utilized larger fish (100-150 mm TL) and resulted in establisment of bluegills.

Within 1 year following successful stocking, bluegills numerically comprised 7-77% of the forage in the five intensive study ponds (Table 2). Lowest impact was in the same pond which was unsuccessfully stocked the first time. In the second year following stocking, percentages increased to 50-96%. Limited data from the third year suggested even higher contributions of bluegills to the forage base. Bluegills showed no indication of overpopulating in any of the ponds.

At the time of bluegill introductions, most bass populations were comprised almost entirely of fish < 250 mm TL. RSD_{250} values ranged from 0-21% for four ponds (Fig. 1). Only Rock Tank had a population structure comprised of a large proportion of fish > 250 mm TL, but only a few of them were over 300 mm TL, as indicated by an RSD_{300} of 13%.

Bass RSD values varied within and among years for each pond (Fig. 1). Most pronounced effects occurred in PMS-Old, where both RSD_{250} and RSD_{300} values increased substantially. RSD_{250} also increased in Road, but steadily declined in Yoponderosa. Rock Tank, the largest pond, showed stable RSD values throughout the study. Values for Old House II fluctuated erratically, but some of the variation was likely due to sample size, e.g. only 14 fish were used in the RSD calculation for the sample 1 year after stocking. This pond, however, was the one in which bluegills comprised only 7% of the forage at that time. Other fluctuations likely occurred due to seasonal variations in sampling efficiency and annual variations in recruitment. Effects due to fishing were probably minimal since all ponds were subject to limited fishing pressure.

Bass in all ponds showed an increase in condition, as measured by K_{TL} and

W_r, following bluegill introduction, although this was delayed for 2 years in two ponds. Significant increases in condition were found in PMS-Old and Road (Fig. 2). Only in PMS-Old did W_r weight reach the standard weight, but we have seldom found W_r values ≥ 1.0 anywhere in Texas ponds, even those wit bluegills as forage (unpublished data).

Success in impacting bass populations appeared to be independent of stocking rate and size of bluegills stocked, except that bluegills in Old House II were successfully established when larger bluegills were used. Impacts on bass RSD and condition generally occurred more quickly in the thre larger ponds.

For bass ponds lacking bluegills, stocking of 75 - 100 bluegills/hectare at lengths $\geq$75 mm TL is recommended. Such stocking can provide economical corrective management.

ACKNOWLEDGMENTS

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Table 1. Characteristics of study ponds used to determine effects of stocking bluegills into Texas bass ponds previously lacking bluegills as forage, 1978-1981.

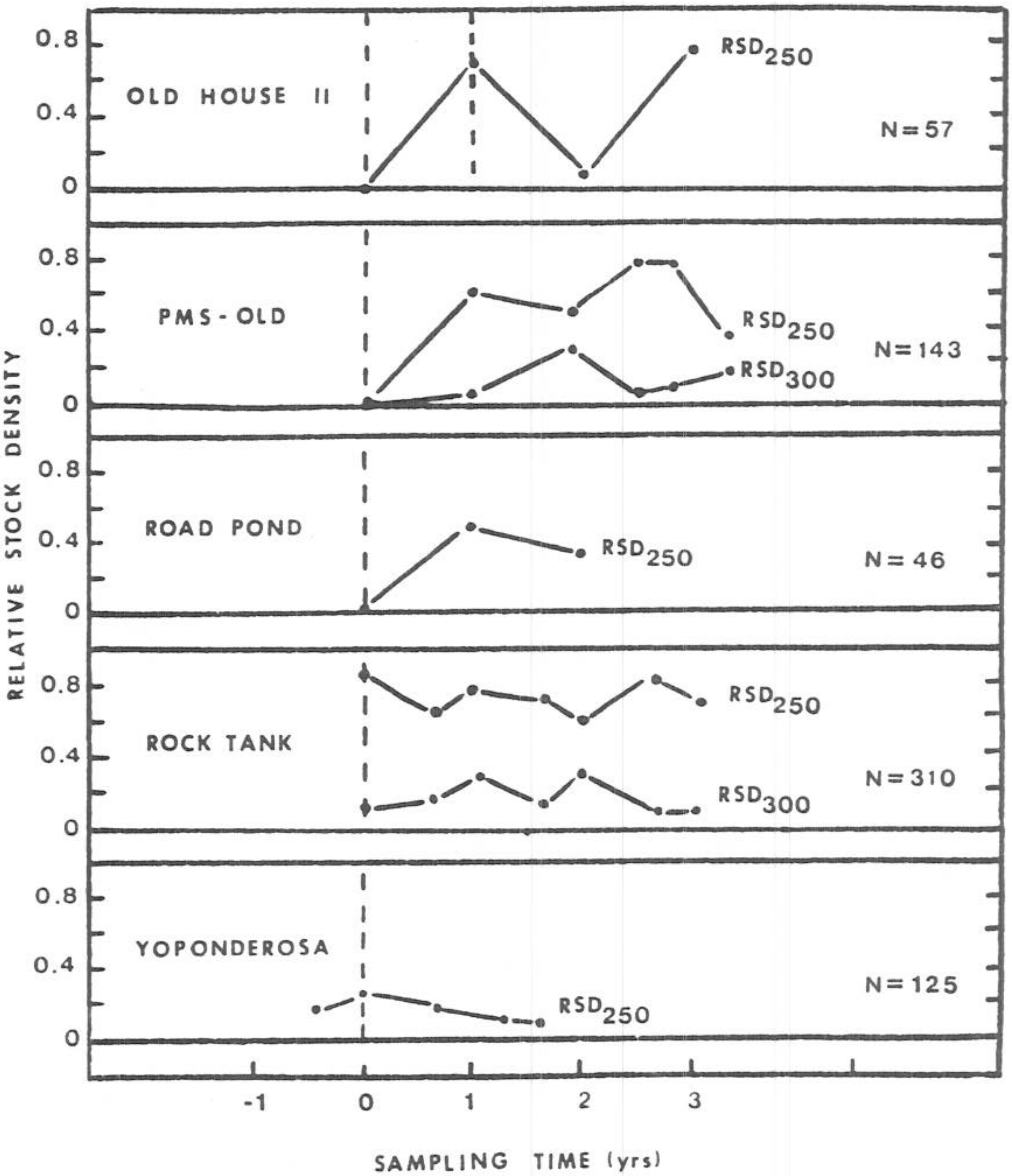
Pond	Location (county)	Surface area (hectares)	Secchi disk (cm)	Forage species	Bluegills stocked	
					No./hectare	TL(mm)
Old House II	Limestone	0.20	> 100	Green sunfish	250[a]	~75[a]
PMS - Old	Falls	1.54	30-90	Green sunfish Redear sunfish Golden shiner	65	75-150
Road	Maverick	0.23	20-40	Mosquitofish	109	75-150
Rock	Webb	12.15	> 100	Green sunfish Mosquitofish Warmouth	72	~75
Yoponderosa	Brazos	3.24	20-40	Redear sunfish Golden shiner Mosquitofish Warmouth	90	75-150
Hilltop	Limestone	0.40	60-80	Green sunfish	111	~75
Twin Willow	Limestone	0.05	> 100	Green sunfish	400	~75
June	Bexar	4.00	> 100	Green sunfish	74	75-150

[a] This stocking was unsuccessful; consequently a second stocking was made 1 year later with 100-150 mm fish at 125/hectare.

Table 2. Forage species and percent composition of forage, in parentheses, before and after bluegill stocking in five study ponds (GSF=green sunfish, GSH=golden shiner, BG=bluegill, RE=redear sunfish, MQ=mosquitofish, WM=warmouth, and NR=no record).

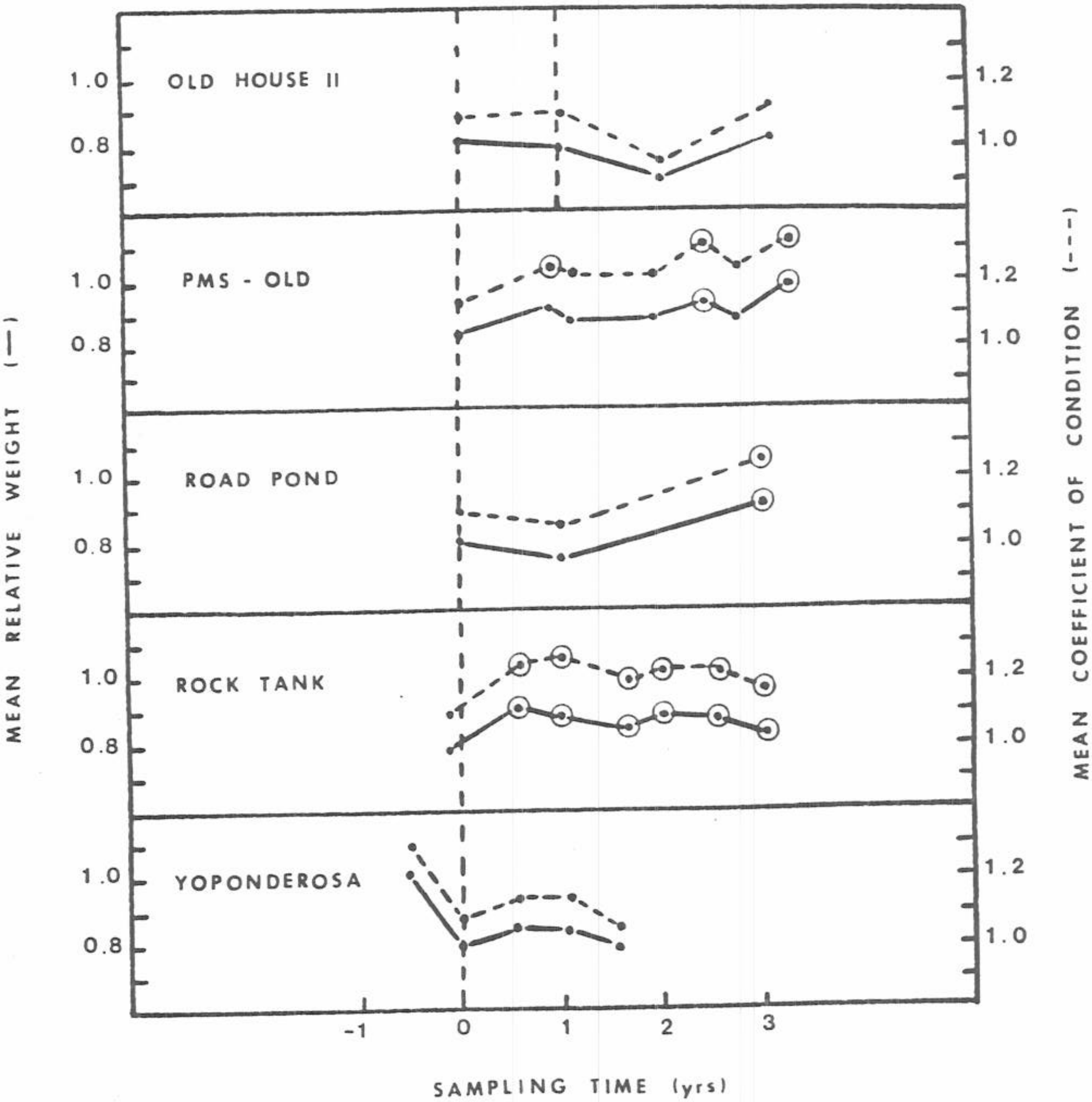
Pond	Pre-stocking	Post-stocking year 1	2	3
Old House II	GSF (100)	GSF (93) BG (7)	BG (96) GSF (4)	--- ---
PMS - Old	GSF (NR) GSH (NR)	GSH (83) BG (17)	BG (84) GSF (7)	BG (82) GSF (13)
Road	MQ (100)	BG (73) MQ (27)	--- ---	BG (100)
Rock	GSF (74) WM (26) MQ	BG (65) WM (13) GSF (22)	BG (76) GSF (17) WM (6)	BG (82) GSF (11) WM (7)
Yoponderosa	WM (53) RE (27) MQ (13)	BG (77) RE (17) WM (3) GSH (2)	BG (50) RE (16) WM (4) GSH (3)	--- --- --- ---

Figure 1. Relative stock density (RSD_{250} and/or RSD_{300}) of largemouth bass in five study ponds. Dashed vertical line(s) indicate time of bluegill introduction.



OLD HOUSE II
N=57
PMS-OLD
N=143
ROAD POND
N=46
ROCK TANK
N=310
YOPONDEROSA
N=125
RSD250
RSD300
0.8
0.4
0
RELATIVE STOCK DENSITY
-1
0
1
2
3
SAMPLING TIME (yrs)

Figure 2. Mean relative weight (W_r) and mean coefficient of condition (K_{TL} for largemouth bass $\geq$ 152 mm TL in five study ponds. Dashed vertical line(s) indicate time of bluegill introduction. Circle values are significantly ($p<0.05$) greater than those at the time bluegill introduction.


OLD HOUSE II
PMS - OLD
ROAD POND
ROCK TANK
YOPONDEROSA
1.0
0.8
1.2
1.0
MEAN RELATIVE WEIGHT (—)
MEAN COEFFICIENT OF CONDITION (- - -)
-1
0
1
2
3
SAMPLING TIME (yrs)

TX AFS Vol 5

HEAT TOLERANCE OF REDBAND TROUT

by

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ABSTRACT

Upper lethal temperatures (LT_{50}) were determined for redband trout (Salmo sp.) that had been acclimated to 15, 20 and 23 C and exposed to temperature increases of 0.5 C/day until death. Temperatures at time of death ranged from 25.5 to 27.7 C. The LT_{50} for fish acclimated to 20 C (27.4) was significantly higher ($\alpha = 0.05$) from those of 15- (27.1) and 23-C (26.8) acclimated fish.

INTRODUCTION

Trout fisheries in Texas depend entirely on stocking harvestable size rainbow trout (Salmo gairdneri) for put-and-take fisheries. Usually fishing is restricted to cooler months (November - March) when water temperatures are favorable for trout survival and stockers are available. Because of poor over-summer survival of stocked trout only limited year round fishing is provided. Fishery biologists in Texas are currently experimenting with trouts reportedly to be tolerant of warm water in an effort to expand the existing fisheries and fishing season. One of these fish is the redband trout (Salmo sp.).

Redband trout are native to the upper Pit and McCloud Rivers in northern California and to desert basins of southeastern Oregon (Behnke 1970; Schreck and Behnke 1971; Legendre et al. 1972; Hoopaugh 1974; Wilmot

1974; and Behnke 1979). Redband trout are known to thrive at elevated temperatures in harsh environments unfavorable for hatchery produced rainbow trout. They can be found in stagnant pools of intermittent streams and water with high alkalinity at 28.0 - 29.5 C (W. Hosford, Oregon Department of Fish and Wildlife, Hines, Oregon, personal communication; Behnke 1980).

Taxonomic classification precludes redband trout as a distinct species (Behnke 1970; Hoopaugh 1974; Robins et al. 1980). R.J. Behnke, Cooperative Fisheries Unit, Fort Collins, Colorado, (personal communication) acknowledges it is a subspecies of rainbow trout based on Jordan and Evermann's (1896) description of an inland form of rainbow trout (S. g. gairdneri) with type characteristics of redband trout. The redband possesses some characteristics of rainbow, cutthroat (S. clarki) and golden (S. aquabonita) trout (Behnke, 1970), however, it is distinguished by coloration, spotting and meristic counts (Schreck and Behnke 1971; Legendre et al. 1972; Behnke 1979).

Behnke (1979) denotes Kamploops trout of British Columbia are redband trout. Black (1953) determined the upper lethal temperature for Kamploops fingerlings to be 24.0 C when acclimated to 11.0 C. Although this provides some guidance in regard to the temperature tolerance of this species complex, lethal temperatures for desert basin redband trout have not been determined. This information is needed to evaluate their potential as a sport fish in Texas. To provide this more definitive information a laboratory study was conducted to describe and evaluate from a fishery management perspective the upper lethal temperature (LT_{50}) of redband trout originating from a desert region.

MATERIALS AND METHODS

Redband trout were obtained from the Fish Cultural Development Center, Bozeman, Montana in August, 1981. Eggs originated from fish spawned in

Parsnip Reservoir in southeastern Oregon (Behnke 1982; W. Hosford, personal communication). Fish were air-freighted to Heart of the Hills Research Station, Ingram, Texas where they were maintained indoors at 14 - 16 C for 4 months prior to temperature acclimation.

Groups of 30 fish were acclimated to constant temperatures of 15, 20 and 23 C at a rate of 1 C/day. Mean total length and weight of test fish were 130 mm (SD = 18) and 29 g (SD = 12), respectively. All fish were held at acclimation temperatures for a minimum of 14 days before testing. Cylindrical 800-1 fiberglass tanks (diameter = 91.4 cm) served as control and test tanks. Temperatures in all tanks were regulated by thermostatically controlled cooling or heating units accurate to ± 0.1 C. Air was bubbled into all tanks to insure mixing of heated or cooled water. Water passed through gravel and rock filters and larger waste material that accumulated on the bottoms of the tanks was siphoned daily. Fish in all tanks were fed a sinking pelleted feed (38% crude protein) at 4.0% body weight/day.

Testing took place in two tanks. Each tank was divided with netted frames into three compartments. Fish were randomly assigned to tanks and compartments. The electrical system used to produce temperature increases consisted of timing devices which controlled thermostatically regulated heating elements. When the water temperature in test tanks was 15 C, 10 fish acclimated to 15 C were placed in a compartment in each tank. Temperature was increased 0.5 C/day until it reached 20 C. Ten fish acclimated to 20 C were then placed in a second compartment in each of the two tanks. Temperature was again increased 0.5 C/day until it reached 23 C. Ten fish acclimated to 23 C were then placed in the third compartment in each test tank. The 10 remaining fish in each acclimation tank served as controls. Water temperature in the test tanks was then increased 0.5 C/day until all fish died.

Temperatures were recorded when fish stopped feeding and when individual deaths occurred. Fish were considered dead when they lacked opercular movement and did not respond to touch (Otto and Rice 1977). Data was combined by acclimation temperature. LT_{50}'s were calculated as defined by Otto and Rice (1977) as the point at which 50% of the fish died from the regression of percentage cumulative mortality (arcsin transformation) on lethal temperature. Analysis of covariance (Sendecor and Cochran 1978) was used to evaluate differences in slope between regression lines for each acclimation temperature. The Newman-Kuels multiple range test (Zar 1974) was employed to designate inter-slope differences.

RESULTS AND DISCUSSION

One mortality occurred in 23-C controls. Fish acclimated to 15 and 20 C ceased feeding at 27.0 C and fish acclimated to 23 C stopped feeding at 25.5 C. Lethal temperatures ranged from 25.5 to 27.7 C (Table 1).

Analysis of covariance showed a significant difference in slopes between regression lines ($\alpha = 0.05$). The Newman-Kuels test indicated the slope from the regression for fish acclimated to 20 C was different from the slopes obtained from other acclimation temperatures because fish acclimated to 20 C died at a higher rate (Figure 1). The slopes of regression lines for 15 and 23 C were found similar. The LT_{50} for fish acclimated to 15, 20 and 23 C was 27.1, 27.4 and 26.8 C, respectively (Table 1).

Although LT_{50} differences were not large there were differences in death temperatures (Table 1). There were no deaths in fish acclimated to 20 C until 27.2 C, but mortalities began at 25.5 C for 15- and 23-C acclimated fish. Higher heat tolerance of fish held at 20 C is not clearly understood, however, fish may have been in better initial condition than fish held at other temperatures. Weight gain in 20-C controls was 5.5 and

8.8 g more than in 15- and 23-C controls, respectively. Redband trout fingerlings (2-12 g) were shown to gain more weight when held at 19 C than at 4 - 16 C (P. Dwyer, Fish Cultural Development Center, Bozeman, Montana, personal communication), whereas, rainbow trout fingerlings gained more weight at 16 C than at 19 C (Dwyer et al. 1981). Redband trout, adapted to desert heat, would seemingly optimize at warm temperatures. Therefore, redband trout reared at 18 C to 20 C would perhaps have the best chance of enduring summertime water temperatures.

Most importantly, heat tolerance of redband trout should be compared to rainbow trout, the species currently stocked in Texas. Upper incipient lethal temperatures for rainbow trout have been reported to be 24.0 - 27.0 C (Craige 1963; Bidgood and Berst 1969; Bidgood 1980). Vancil et al. (1979) determined the ultimate upper lethal temperature for Lake McConaughy (Nebraska) rainbow trout to be > 26.0 C but < 28.0 C. Results of this experiment show redband trout apparently have upper lethal temperatures comparable to Lake McConaughy rainbow trout. Kaya (1978) determined rainbow trout originating from a permanently heated stream did not have higher upper incipient lethal temperatures (25.0 C - 26.2 C) than hatchery rainbows (23.2 C - 26.2 C) although the former reputedly thrive in natural habitat up to 28.8 C (Kaya 1977).

Although redband trout are reported to survive up to 29.5 C, LT_{50} values ranged only from 26.8 to 27.4 C. Inherent thermal resistance of redband trout may be daily temperature extremes tolerated rather than upper lethal temperatures (R.J. Behnke, personal communication). Redband trout survive diurnal temperature ranges of 13.0 to 29.0 C (W. Hosford, personal communication). Standard temperature tolerance testing does not examine this information. An alternative may be long-term experiments approximating the natural cyclic thermal regime (i.e., heating during the day, cooling at night) of candidate waters. This type of testing may show differences in species by their ability to recover from, rather than withstand high temperatures as would occur naturally. The critical thermal maximum, CT_{max} (Huntsman and Sparks 1924) appears to be a good test where fish would be exposed to quickly changing temperatures, for example in power plant cooling lakes, but is impractical for most natural settings where trout are considered. Lee and Rinne (1980) showed no differences in CT_{max} for five species of trout.

Behnke (1979) noted, "For warm-adapted trout, the genetic resources available in the arid lands would appear promising." Considering the thermal regime in Texas rivers, for example, availability of cool springs and cooler temperature at night, redband trout are good candidates to enhance trout fishing in Texas.

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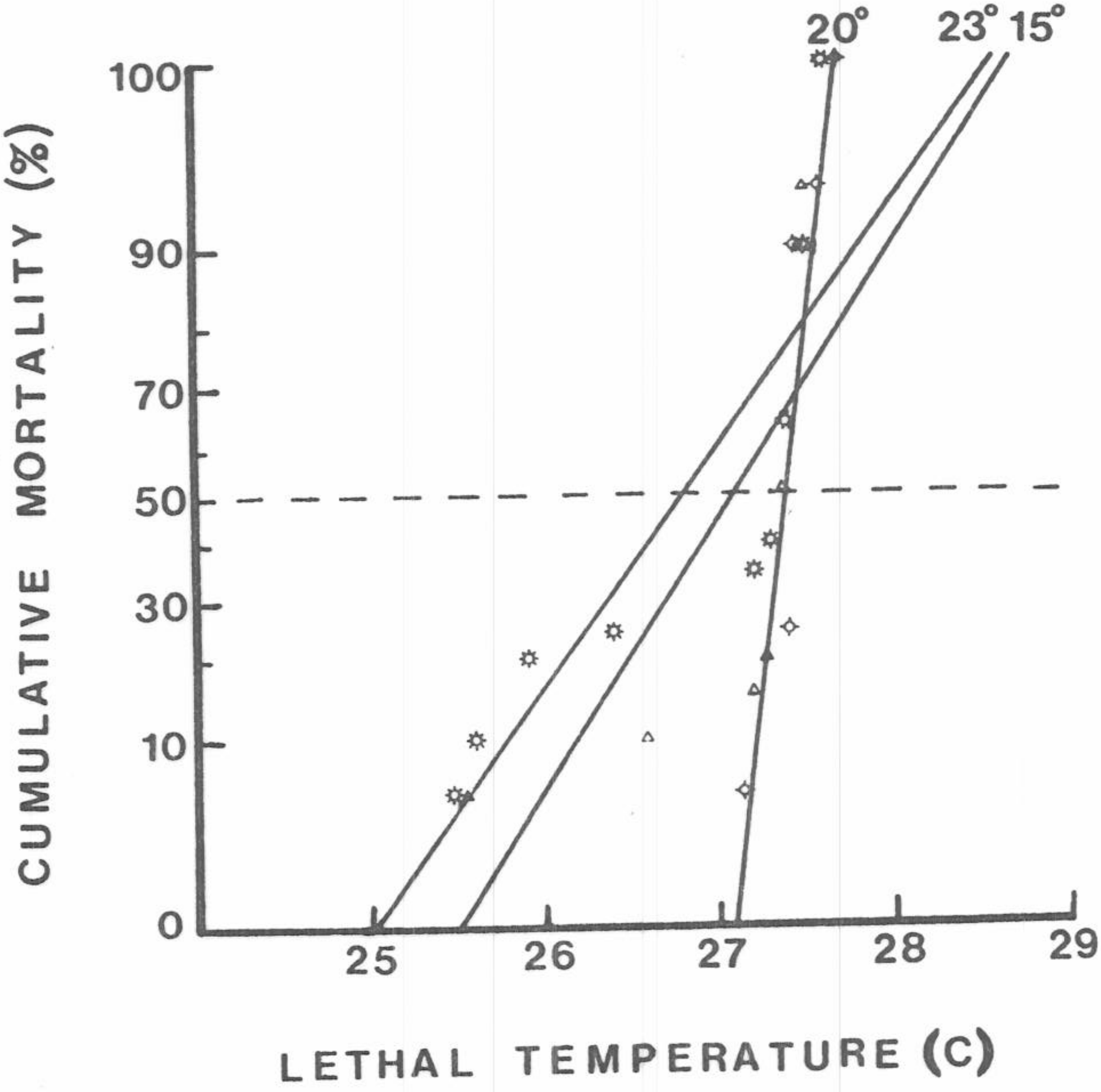
Table 1. Upper lethal temperatures for redband trout acclimated to three temperatures and exposed to temperature increases of 0.5 C/day.

Acclimation temperature (C)	n	Lethal temperature range (C)	LT_{50} (C)	Regression[a] equation (arcsin Y=a+bX)	r^2
15	20	25.5-27.7	27.1	Y=-720.09+28.23(X)	0.492
20	20	27.2-27.7	27.4	Y=-4485.0+165.30(X)	0.942
23	20	25.5-27.6	26.8	Y=-621.36+24.85(X)	0.712

[a] Y = percent cumulative mortality, a = Y-intercept at X = 0, b = slope, and X = lethal temperature.

Figure 1. Cumulative mortality (plotted with the arcsin transformation) vs. lethal temperature for redband trout acclimated at 15, 20 and 23 C and exposed to temperature increases of 0.5 C/day until death. Data points referring to 15 C are indicated by △ , 20 C by ✧ , and 23 C by ✡ . LT_{50}'s are indicated by the intersection of regression lines and the 50% cumulative mortality line.


20°
23°
15°
100
90
70
50
30
10
0
CUMULATIVE MORTALITY (%)
25
26
27
28
29
LETHAL TEMPERATURE (C)